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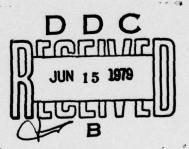
The 1978 NRL Air Quality Data

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Radiological Protection Staff Division

May 21, 1979

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This report is a summary of the air quality data measured at NRL for the calendar year 1978. This annual summary is part of a continuing series of yearly reports initiated in 1975. The variables measured at the NRL air monitoring station include ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), carbon monoxide (CO), wind speed, and wind direction. The instruments used to measure these variables are interfaced to the data acquisition system which in turn is coupled to a magnetic tape recorder. The data input is for one month on the tape which is subsequently analyzed by the air quality computer program

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20. Abstract (Continued)

at the NRL Research Computer Center and results in a monthly computer printout of the air quality data. Each monthly computer prinout is then analyzed and a digest of the information obtained is reported as the yearly summary.

CONTENTS

THE 1978 NRL AIR QUALITY DATA

INTRODUCTION

This report is the fourth in a continuing series of yearly summaries of air quality data measured at NRL (1,2,3,4). The present review includes data for the calendar year 1978. The variables measured during this time were ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), carbon monoxide (CO), wind direction, and wind speed. During the latter part of 1978 instruments were installed at the NRL air monitoring station for measuring nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), air temperature, and relative humidity, but not enough data were generated to be included in the 1978 report.

The purpose of the present report is to summarize, characterize, and interpret the large amount of air quality data monitored at NRL. Only the main features of the analysis will be reported.

BACKGROUND

The NRL air monitoring station is located in Building 207, Room 409. Details of the housing and instruments in use have been reported in previous publications (1,2,3,4,5). The instruments in use are interfaced to a data acquisition system which is, in turn, coupled to a magnetic tape recorder. The input on the magnetic tape is in 5-minute time-averages. A tape is run continuously for one month and the data is retrieved, via the air quality computer program, with a computer printout of the essential information (6). Examples of typical monthly computer printouts are given in the previous yearly summaries (1,2,3). The air quality data from the monthly computer printouts are used to extract the information contained in this report.

AIR QUALITY DATA AND RESULTS

Valid Observations

Table 1 lists the number of valid hourly observations of each variable measured during each month of 1978. Included in the table are the total number of valid hours, percent of valid hours

Note: Manuscript submitted March 28, 1979.

1

based on the total number of hours in one year, and the total number
of 5-minute observations for each variable. It will be noted from
inspection of the table that the data for the months of February and
March are missing. This is because the data acquisition system was
sent to the supplier for addition and modification of extra channels
to accommodate the expansion of the air monitoring program to
include measurements of air temperature, relative humidity, and
nitrogen oxides. It will also be noted from the table the inclusion
of a column for RHC. This is the symbol used in this report for
non-methane hydrocarbons and its concentration values are obtained
by subtracting the methane concentration from the total hydrocarbon
concentration in a given time, i.e., THC-CH$_4$ = RHC.

		O_3	SO_2	NO_2	THC	CH_4	RHC	CO	WD &** WS
	J	648	647	625	647	647	647	647	648
	A	334	258	267	283	283	283	282	334
	M	549	549	549	549	549	549	549	549
	J	552	534	544	485	485	485	486	552
	J	594	502	460	594	594	594	594	594
	A	670	607	574	538	535	538	538	672
	S	552	552	552	552	552	552	552	552
	O	582	582	---	508	508	508	508	582
	N	672	688	---	628	628	628	628	696
	D	404	404	405	377	377	377	377	405
total hours		5587	5313	3976	5160	5160	5160	5161	5584
1 yr		8760	8760	8760	8760	8760	8760	8760	8760
%		63.8	60.7	45.4	58.9	58.9	58.9	58.9	63.7
total 5-min avg.		67,044	63,756	47,712	61,920	61,920	61,920	61,932	67,008

TABLE 1
VALID NUMBER OF HOURS OF MEASUREMENTS*

*   February and March data are not available

** wind direction (WD) and wind speed (WS)

It is clear from inspection of Table 1 that there are a large
number of data points available for analyzing the air quality data.

However, it would have been better if at least 75% of the total number of hours in a year (6,570 valid hours) had been available for analysis. Generally though it is difficult to achieve this goal because of the downtimes of the instruments due to frequent calibration periods, malfunctions and modifications that are continually going on to assure reliable measurements. In addition, the monthly run is usually started on the first working day of the month and terminated on the last working day of the month. This procedure also cuts down on the available number of hours of observation. At other times, the occasional power transients in the electrical lines (glitches) are troublesome and interfere with the smooth operation of the data acquisition system. This problem is particularly irksome since the air monitoring system is a continuous operation and any powerful glitch can invalidate a large number of hourly observations. A continuing goal of the air monitoring program is to increase the number of valid hourly observations for each variable being measured to at least 85% of the total hours in a given year (or month). At the same time it would also be desirable to have as many 24-hour averages as possible. These goals are desirable because it would allow a more comprehensive analysis of daily and seasonal trends to be discerned in pollutant behavior. For example, it would be easier to determine if pollutants show systematic variations or irregular variations in their concentration profiles in a given sampling time.

It is worth mentioning here that all hourly observations are based on 5-minute averages so that in one hour there are twelve measurements upon which the one hour average is based. Generally, short time periods are known as time-averages and longer periods as sampling times, depending on the use one wants to make of the concentration data. For example, in a 5-min/1-hr system the 5-min period is the 5-min time-average and the 1-hr period is the sampling time, while in a 1-hr/24-hr system, the 1-hr period is the 1-hr time-average and the 24-hr period is the 24-hr sampling period.

Meteorological Data

Table 2 lists the percent of occurrence of each wind direction for each month of 1978 for which data were available, and includes the total percent occurrence for each wind direction during the year. It will be noted from inspection of Table 2 that the prevailing wind direction for the calendar year 1978 was south (S), followed closely by NNW. These two wind directions are always at the top of the list as one of the prevailing wind directions. It is also of interest to note that a prevailing wind direction does not occur more than 15% of the time in any given year; and at NRL somewhat less than this percentage: (1975-NNW-14.2%, 1976-NNW-12.7%, 1977-NNW-12.9%).

3

		J	A	M	J	J	A	S	O	N	D	total % Occur.
TABLE 2													
PERCENT OCCURRENCE OF WIND DIRECTIONS*													

		J	A	M	J	J	A	S	O	N	D	total % Occur.
1	N	9.1	8.4	9.3	7.1	9.1	7.6	5.3	6.7	11.9	4.0	8.1
2	NNE	9.4	9.0	5.5	5.3	3.9	4.9	9.4	7.9	17.2	3.2	7.1
3	NE	5.2	14.7	7.3	1.8	4.0	4.5	8.0	5.2	9.3	2.7	6.1
4	ENE	3.5	5.7	4.7	1.3	2.7	1.8	5.3	1.2	4.7	2.0	3.2
5	E	1.5	2.7	3.8	1.4	1.9	2.4	3.4	2.1	5.2	1.5	2.6
6	ESE	2.2	3.3	3.3	0.5	0.5	1.8	3.3	0.9	3.0	1.0	2.1
7	SE	1.7	3.6	2.4	2.0	0.5	2.7	3.3	0.9	2.2	3.0	2.1
8	SSE	4.7	7.2	10.6	6.9	6.6	7.4	7.4	5.3	6.6	5.9	6.8
9	S	6.9	4.5	16.0	16.1	21.5	13.7	15.9	14.6	7.6	8.1	12.8
10	SSW	3.2	4.5	10.2	15.8	16.3	14.0	8.0	14.1	5.6	10.4	10.5
11	SW	3.2	2.1	4.6	12.1	10.4	15.8	14.5	12.4	4.7	11.4	9.3
12	WSW	5.6	3.0	1.8	5.4	6.7	5.7	6.3	3.4	3.4	5.4	4.8
13	W	3.5	3.3	1.6	0.9	1.9	1.9	2.2	2.4	1.7	4.9	1.5
14	WNW	6.0	4.8	0.9	2.9	2.0	2.7	0.4	1.4	1.9	6.7	2.8
15	NW	17.3	9.3	4.2	4.9	3.4	4.8	1.8	8.6	5.9	16.5	7.4
16	NNW	17.3	14.1	1.38	16.7	8.6	8.8	5.6	13.4	9.8	13.0	12.6

* February and March data are not available

Since there are sixteen wind directions listed in the table, the probability of occurrence would seem to be 6.25% for each wind direction. According to the data in the table, this is not true because of complex large scale weather systems and demographic and topographic features peculiar to the area. Consequently, air pollution emission sources from the predominant wind directions, S and NNW, will heavily bias the air quality data. For example, some emission sources from the S wind direction ($\pm$ 11.25°) include the Blue Plains sewage treatment facility, Washington Beltway-Route 95 (Wilson Bridge), and residential units. From the NNW wind direction ($\pm$ 11.25°), some emission sources include the Washington National Airport, road traffic, and space heating units. Common emission sources to the S and NNW wind direction are air traffic over NRL and vicinity and minor contributions from NRL itself. The only major emission source of air pollutants at NRL is the heating plant (4,000,000 gallons of fuel oil a year).

Fortunately, as far as NRL is concerned, some of the major air emission sources lie in the sectors with the least percentage of occurrence of wind direction. For example, in the west direction (1.5%) lies a coal-fired electric power plant (1,000,000 tons of coal per year), from the east direction (2.6%) there is Route 295

4

(50,000 motor vehicles per working day), and from ENE (3.2%), ESE (2.1%), SE (2.1%), and WNW (2.8%) there are located heating plants, power plants, and commercial and light industrial facilities. Within a 3-mile radius of NRL there are located, at last count, about fifty-six chimneys and stacks which may be considered as major air emission sources. Consequently, even though NRL may at times be subjected to the effect of some air emission sources, other areas in the region may be more frequently exposed to these same sources. There is also the possibility that any area may be exposed to some pollutants that are not recognized as such, or are not being measured at this time. In any case, because of fluctuating wind directions, over the course, say, of a day, no part of NRL is unduly exposed to emissions from any specific source for a long consecutive period of time. However, prolonged exposure to pollutants may occur when a unique combination of meteorological conditions prevail, and, if persistent over a long period of time, may cause an air pollution episode. These meteorological conditions include a stagnant high pressure area, a temperature inversion (subsidence type, i.e., an inversion aloft), and low wind speeds. Consequently, emissions from all sources add to the pollutant buildup.

It is also interesting to note that higher wind speeds prevail with the NNW direction as compared to the S direction as shown in Table 3 where average wind speed for a given direction are listed for each month of 1978. This suggests that pollutants from emission sources to the NNW of the Laboratory are better mixed in the atmosphere than those pollutants arriving from the S direction. This may be one reason why odors from the Blue Plains sewage plant tend to linger longer within the confines of the Laboratory.

Generally, the average wind speeds are fairly well distributed over all the wind directions as noted in the table. Further, most wind speeds lie between 3.5 - 7.4 mph. Although this wind speed group may appear to be low, it is quite adequate to allow, most of the time, sufficient mixing of the pollutants in the atmosphere and to prevent abnormal buildup of pollutant concentrations. On the other hand, higher wind speeds may allow high concentrations of pollutants to be transported over longer distances. This is especially true with ozone concentrations, since some rather larger concentrations can occur with high wind speeds.

TABLE 3
AVERAGE WIND SPEEDS FOR GIVEN WIND DIRECTIONS*

	J	A	M	J	J	A	S	O	N	D
N	6.3	8.7	7.0	6.6	6.9	6.7	6.9	8.1	7.8	7.7
NNE	6.6	6.7	6.2	6.3	5.4	6.2	7.0	7.5	5.8	4.9
NE	6.8	8.	6.9	6.9	5.9	6.6	7.4	7.5	6.2	5.6
ENE	5.9	9.4	8.2	6.3	6.0	5.4	5.7	6.2	6.7	6.8
E	5.1	6.5	7.8	6.0	5.5	5.3	6.2	7.4	7.7	7.8
ESE	4.1	5.5	6.6	12.0	6.6	6.4	7.2	16.6	7.4	10.7·
SE	6.4	6.5	7.6	7.9	12.7	6.4	6.8	12.8	8.4	7.2
SSE	5.1	5.5	5.9	6.5	5.4	5.2	5.3	7.0	7.4	5.5
S	6.8	5.6	6.7	6.4	5.8	5.4	5.4	5.7	6.7	5.6
SSW	5.9	7.9	5.6	6.1	6.2	6.2	5.8	6.5	6.5	5.9
SW	8.1	7.6	7.2	6.9	8.1	7.1	7.1	7.6	8.6	8.7
WSW	12.3	5.4	5.3	5.8	6.7	6.3	5.4	5.4	710	8.2
W	9.0	6.6	5.2	8.1	6.9	9.4	5.6	6.1	7.0	7.4
WNW	9.1	7.5	6.4	6.0	8.1	7.6	4.6	8.6	9.5	10.2
NW	9.1	7.5	6.4	6.0	8.1	7.6	4.6	8.6	9.5	10.2
NNW	10.6	11.0	9.1	9.4	6.7	7.3	9.0	10.7	9.0	13.5

*February and March data are not available

     Most visible emissions are present in the atmosphere either
as plumes or puffs. Most plumes, shortly after emission, tend to
break up into fragments or in the present context, as puffs. As wind
speeds increase, plumes are more easily broken up into puffs. With
further increase in wind speed, or with increasing distance from the
emission source, the visible characteristics of the puff decreases.
Even with low wind speeds, visible emissions tend to be broken up into
pollutant puffs. One may even envisage a pollutant plume as a con-
secutive series of overlapping puffs. Pollutant puffs may further be
envisaged as having irregular size and shape, and of varying composition
and concentration. If this model is correct, then pollutants are present
in the atmosphere as: a discrete puff, a series of discrete puffs, or
a consecutive series of overlapping puffs (plume). With increasing
turbulence, and/or with increasing distance between emission source
and air sampling site, the pollutants tend to be more evenly distri-
buted throughout the atmosphere, or at least that part of the
atmosphere which is of most concern to us (work, play, live).

     Because of variations in meteorological conditions and
emission sources, some pollutants, at any given time, are better
mixed in the atmosphere than other pollutants. Since emission
sources may be considered to act on a daily schedule (rush hour
traffic, boiler tube blowby, etc.) this would indicate that
meteorological conditions play a predominant role in the mixing
of pollutants in the atmosphere, while emission source variations

have a secondary role. In addition, the chemical and physical properties of the pollutants also have an important part in the mixing process, i.e., solubility in water (rain), reactivity, density, and molecular weight. Furthermore, the closer an air monitoring site is to an emission the less efficient the mixing process would appear to be. Consequently, mixing of pollutants in the atmosphere is hardly ever 100% complete, i.e., the mixing capacity of the atmosphere is rarely of 100% efficiency. With respect to the NRL pollutant concentration data, it is a rare event that a consecutive series of 1-hr averages have the same concentration, or that a similar situation occurs for a group of pollutants.

Air Quality Data

The air quality data measured at the NRL air monitoring station are for ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), non-methane hydrocarbons (RHC), carbon monoxide (CO), wind speed, and wind direction. The gases measured are representative members of classes of pollutants which include oxidants, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon oxides. Pollutants such as SO_2, RHC, and CO are primary pollutants in as much as they are emitted directly into the atmopshere from a random distribution of emission sources; O_3 is a secondary pollutant since it is not emitted from any source but is formed in the atmosphere by a complex series of photochemical reactions involving hydrocarbons, NO_2, sunlight, and temperature (O_3 may also be due to a tropospheric-stratospheric exhange, and from lightning discharges); NO_2 has both a primary and secondary origin since it is a product of high temperature combustion sources, and a product of the atmospheric photochemical process.

Most, if not all, of the pollutants currently being measured at NRL, have an anthropogenic origin. For example, in the Washington metropolitan area, approximately 2 million tons of pollutants are emitted annually into the atmosphere. A large percentage of this tonnage is from motor vehicle exhaust emissions. In fact, the traffic density in this area is greater even than cities like Los Angeles and New York.

Some other emission sources that bias the NRL air quality data (pollutant concentrations) are: Route 295 (50,000 motor vehicles per working day), Wilson Bridge (100,000 motor vehicles per day), air traffic corridor over NRL and vicinity (480 landings and takeoffs per day), and a number of heating plants, incinerators, electric power plants, and space heating units.

7

Some of the results of these emission sources are shown in Tables 4 through 8 and include only the main features of the data analysis for each pollutant. In each table, N is the number of hourly observations for each month, C_{AVG} is the monthly average of the N measurements, $(C_{MAX})_{5-min}$ is the highest 5-min average that occurred in each month, $(C_{MAX})_{1-hr}$ is the highest 1-hr average that occurred in each month, and $(C_{MAX})_{24-hr}$ is the highest daily average that occurred in each month. Included at the bottom of each table is the representative yearly average concentration of the total N measurements, i.e., $(C_{AVG})_{year}$. These average values are only representative of the actual yearly averages since not enough values were available for obtaining a more exact yearly average. However, it is felt that the average value listed in each table is representative or close to the actual yearly value that would have been obtained with additional measurements.

	N (hrs)	C_{AVG}	C_{MAX} 5-min	C_{MAX} 1-hr	C_{MAX} 24-hr
Jan	648	.013	.041	.038	.026
Feb	---	---	---	---	---
Mar	---	---	---	---	---
Apr	334	.034	.083	.080	.043
May	549	.037	.397	.236	.068
June	552	.052	.146	.152	.072
July	549	.035	.133	.129	.048
Aug	670	.038	.187	.168	.062
Sept	552	.030	.129	.125	.055
Oct	582	.055	.487	.172	.082
Nov	672	.012	.068	.063	.025
Dec	404	.006	.013	.012	.009

TABLE 4
AIR QUALITY DATA FOR O_3 IN ppmv

represents yearly average $(C_{AVG})_{year}$ = 0.031 ppmv

	N (hrs)	C_{AVG}	(C_{MAX}) 5-min	C_{MAX} 1-hr	C_{MAX} 24-hr
			TABLE 5		
		AIR QUALITY DATA FOR SO_2 IN ppmv			
Jan	647	.028	.386	.208	.042
Feb	---	---	---	---	---
Mar	---	---	---	---	---
Apr	258	.016	.287	.138	.032
May	549	.037	.397	.236	.068
June	534	.014	.329	.136	.025
July	502	.014	.242	.111	.030
Aug	607	.015	.199	.076	.040
Sept	552	.024	.565	.133	.041
Oct	582	.024	.187	.106	.046
Nov	688	.029	.151	.069	.047
Dec	404	.017	.241	.091	.026

representative yearly average $(C_{AVG})_{year}$ = 0.030 ppmv

	N (hrs)	C_{AVG}*	(C_{MAX}) 5-min	C_{MAX} 1-hr	C_{MAX} 24-hr
			TABLE 6		
		AIR QUALITY DATA FOR NO_2 IN ppmv			
Jan	625	.011	.086	.079	.035
Feb	---	---	---	---	---
Mar	---	---	---	---	---
Apr	267	.087	.142	.130	.099
May	549	.031	.427	.219	.129
June	546	.006	.062	.053	.012
July	460	.025	.210	.206	.103
Aug	574	.011	.093	.076	.037
Sept	552	---	---	---	---
Oct	---	---	---	---	---
Nov	---	---	---	---	---
Dec	408	.015	.412	.400	.036

* not enough data for representative yearly average

9

TABLE 7
AIR QUALITY DATA FOR RHC (NON-METHANE HYDROCARBONS) IN ppmv

	N (hrs)	C_{AVG}	C_{MAX} 5-min	C_{MAX} 1-hr	C_{MAX} 24-hr	C_{MAX} 6-9 a.m.	C_{MAX} 7-4 p.m.
Jan	647	---	5.27	1.03	.28	.22	.75
Feb	---	---	---	---	---	---	---
Mar	---	---	---	---	---	---	---
Apr	283	.02	4.37	0.52	.02	.03	.02
May	549	.10	12.55	2.14	.55	1.31	.69
June	485	.05	4.80	1.93	.08	.18	.08
July	594	.07	12.15	2.58	.54	2.13	.24
Aug	538	.06	4.52	1.83	.21	.13	.08
Sept	552	.02	3.04	.56	.05	.34	.06
Oct	508	.09	7.90	5.09	.37	1.07	.15
Nov	628	.28	13.24	2.60	.58	1.17	.39
Dec	377	.89	5.85	5.77	4.83	4.62	5.09

representative yearly average $(C_{AVG})_{year}$ = 0.12 ppmv

TABLE 8
AIR QUALITY DATA FOR CO IN ppmv

	N (hrs)	C_{AVG}	C_{MAX} 5-min	C_{MAX} 1-hr	C_{MAX} 24-hr	C_{MAX} 8-hr
Jan	647	1.45	8.37	7.19	2.91	5.08
Feb	---	---	---	---	---	---
Mar	---	---	---	---	---	---
Apr	283	1.10	5.15	2.27	1.38	1.66
May	549	1.24	22.05	18.82	2.13	4.72
June	486	1.06	4.63	3.57	1.53	2.28
July	594	1.06	3.98	3.03	1.25	2.82
Aug	538	1.25	5.78	4.21	2.29	2.96
Sept	552	1.14	43.04	5.32	1.33	2.10
Oct	508	1.56	12.51	10.35	3.37	6.97
Nov	628	2.25	13.59	9.02	4.19	6.99
Dec	377	1.52	8.12	5.19	2.39	3.75

representative yearly average $(C_{AVG})_{year}$ = 1.39 ppmv

10

A common feature in each of the tables is that, for each pollutant, in any given month, the shorter the time-averaging period the higher the concentration. This is a result of the laws of probability since there are more measurements in a short time-averaging period than in a longer time-averaging period (see Table 1). However, the frequency of occurrence of large concentration values is decreased with shorter time-averaging periods. Even so, some extreme concentration values do occur, especially with the 5-min and 1-hr maximum concentration values. These values may be compared, in any given month, with the 24-hr average and monthly averages listed in the tables. It is fortunate that the maximum 5-min and 1-hr concentration values are not extended over longer periods of time. Present indications are that this situation is unlikely to occur with most pollutants. An exception is O_3, for which some high hourly concentrations have occurred for long periods of time.

The effect of pollutants on flora, fauna, and materials depend on the intensity of concentration and time. Depending on the initial condition of the recipient, a short term exposure to a high concentration of a given pollutant may be just as detrimental as long term exposure to low concentrations. To protect human health and welfare, federal and local air quality standards have been established for a number of pollutants. Table 9 lists the federal primary and secondary air quality standards for SO_2, CO, O_3, RHC, and NO_2 for given time-averages while Table 10 lists the District of Columbia primary and secondary air quality standards for the same pollutants. The only difference between the two tables is that the District of Columbia standards for SO_2 are more restrictive than the federal SO_2 standards. In both tables, the number of times the standards have been exceeded, during 1978, are also listed.

The excessive number of times the O_3 standard has been exceeded is not as disturbing as it might be since EPA is changing the O_3 standards to 0.12 ppmv, effective in 1979 (it should be recalled that O_3 is not emitted into the atmosphere but is formed there by a complex series of photochemical reactions involving hydrocarbons, nitrogen dioxide, sunlight and temperature).

Tables 9 and 10 do not include the particulate matter air quality standards since this pollutant is not currently being measured at NRL.

11

TABLE 9 NATIONAL AMBIENT AIR QUALITY STANDARDS IN ppmv			Times Exceeded at NRL
SO₂	0.03 (aam)*	- primary	
	0.14 (24-hr)	- primary	0
	0.50 (3-hr)	- secondary	0
CO	9 ppmv (8-hr)	- primary-secondary	0
	35 ppmv (1-hr)	- primary-secondary	0
O₃	0.08 ppmv (1-hr)	- primary secondary	483
RHC	0.24 ppmv (3-hr)	- primary-secondary	24
NO₂	0.05 ppmv (aam)*		-

*annual arithmetic mean

TABLE 10 D. C. AMBIENT AIR QUALITY STANDARDS IN ppmv			Times Exceeded at NRL
SO₂	0.29 ppmv (aam)*	- primary	
	.109 ppmv (24-hr)	- primary	0
	.323 ppmv (1-hr)	- primary	0
	0.020 ppmv (aam)*	- secondary	
	0.086 ppmv (24-hr)	- secondary	0
	0.273 ppmv (1-hr)	- secondary	0
CO	9 ppmv (8-hr)	- primary	0
	35 ppmv (1-hr)	- secondary	0
O₃	0.08 ppmv (1-hr)	- primary & secondary	483
RHC	0.24 ppmv (3-hr)	- primary & secondary	24
NO₂	0.05 ppmv (aam)*	- primary & secondary	-

*annual arithmetic mean

12

Air Quality Trends

For pollutants and gases like O_3, SO_2, NO_2, THC, and CH_4, approximately two-thirds of the 1-hr averages are below the monthly average in any given month. On the other hand, pollutants like RHC and CO reveal a significantly different behavior since RHC had approximately 81% and CO had approximately 73% of the 1-hr data below the monthly averages. These percentages indicate that pollutant concentrations in air do not have a normal Gaussian distribution, but roughly approximate a log-normal type of distribution. The actual distribution is more complex than this if all the data are taken into account, say, all the 1-hr averages in one month. However, if certain restrictions are placed on the data, such as wind direction, then the data more nearly approximates a log-normal distribution.

TABLE 11
NUMBER OF TIMES HOURLY MAXIMUM CONCENTRATIONS OCCURRED
AT DIFFERENT TIMES OF DAY*

Hour Beginning At	O_3	SO_2	NO_2	THC	CH_4	RHC	CO
00 (midnight)	2	11	16	16	10	18	24
01	5	6	5	11	13	9	4
02	4	5	4	7	15	5	4
03	1	8	2	9	8	6	4
04	3	8	1	8	12	12	2
05	3	6	1	7	7	3	1
06	0	12	4	13	20	5	5
07	1	11	10	9	6	15	20
08	0	14	8	12	5	8	31
09	3	11	4	6	3	12	14
10	2	9	4	0	5	2	2
11	3	10	2	1	1	2	3
12 (noon)	15	10	3	1	1	4	1
13	42	11	3	2	2	5	1
14	52	5	0	1	2	2	0
15	50	7	1	4	2	4	3
16	22	7	0	5	4	4	1
17	23	8	3	2	6	4	4
18	13	5	7	6	6	4	8
19	6	5	5	6	4	9	2
20	1	13	6	15	11	12	6
21	5	7	8	12	11	10	10
22	2	10	10	16	16	16	15
23	10	18	15	33	37	25	29

*based on local time

Another interesting feature of pollutant concentrations in air is the time of day in which the maximum 1-hr concentrations occur. Table 11 lists the number of times the maximum 1-hr concentration occurred in each 24-hr period (from midnight to midnight) for which data were available.

For O_3, most of the 1-hr peak times occurred between noon and 7 p.m. For SO_2, there is no conclusive evidence that there is a particular time of the day when peak 1-hr concentrations occur. This is an example of an irregular variation while the O_3 data reveal a systematic variation. For NO_2, the data is erratic but appear to show that there are two peak periods; one in the mid-morning hours and one in the late evening and early morning hours. NO_2 may be considered to have a systematic variation of the data. For THC, CH_4, and RHC, the data in Table 11 reveal that there is a noticeable dip in the number of times in which the peak times occurred between the hours of 10 a.m. and 8 p.m. This is an interesting result since there is no reasonable explanation why the peak times occur when they do. Perhaps this is fortunate since by the time of day in which the photochemical reaction sequence is initiated the hydrocarbons are, by this time, well diluted. Otherwise, the O_3 concentrations would be higher than they are at present. For CO, the 1-hr data reveal two peak times, analagous to the NO_2 data; one peak period is in the midmorning hours and one at the late evening hours. For both NO_2 and CO, the peak midmorning hours correspond to the morning rush hour traffic period but, conversely, the late evening peak times do not correspond to the evening rush hour traffic. There is, as yet, no other explanation for this discrepancy. In any case, the CO data also reveal a systematic variation with the peak times.

Although there are peak times of the day in which the peak concentrations of most pollutants occur, there does not appear to be a peak day, or days in which high concentrations occur. An analysis of the 1-hr data has shown that peak concentrations can occur on any day of the week, including Saturday and Sunday. Even though the traffic patterns have shifted during the weekend from urban to suburban areas, there is apparently enough activity going on to generate the usual amount of pollutants as found during the normal working days. Also, it would appear as if there are no significant cutbacks in heating and electric power requirements during the weekends and emissions from these sources contribute their usual air burden to the atmosphere. With the announced energy shortage for 1979, the weekend picture may change.

14

Another characteristic of pollutant concentrations is their seasonal trend. O_3, for example, has the highest concentrations occurring during the summer (warmer) months. The reasons for this are that the conditions favorable for photochemical reactions, i.e., sunlight and air temperature, are more available during these months. CO, as a general rule has the highest concentrations during the winter (colder) months. Since CO is mainly due to motor vehicle exhaust emissions, it seems likely that the more frequent traffic jams and cold engine start-up during the colder months contribute to the higher CO concentrations. For SO_2, the highest concentrations occurred in the spring of 1978, specifically, during the month of May. Generally, the higher SO_2 concentrations occur during colder months. For NO_2, the highest concentrations occurred during the spring season. This is a fortunate occurrence since NO_2 is a prerequisite for O_3 formation and, since the summer months are optimum for oxidant concentrations, the lower the NO_2 concentrations are during this period the better. For THC, CH_4, and RHC, the highest concentrations generally occur during the spring and winter months. For 1978, most of the higher concentrations for these gases occurred during the winter months. Again, the data show systematic and irregular variations with the seasons. Pollutants like O_3 and CO have definite systematic seasonal variations, while the other pollutants have seasonal trends that vary from year to year. For 1978, pollutants and gases like SO_2, NO_2, THC, CH_4, and RHC also had systematic seasonal variations with respect to their maximum concentrations.

The cohesive picture that emerges from pollutant concentration behavior in air is remarkable when one considers the many factors that would tend to alter these trends. This is a result of the systematic routine emission schedule and the systematic variation of some meteorological conditions on a daily basis. When irregular variations occur in the system, such as road and roof tarring operations, training exercises at the D. C. Fire Department Training Facility (across from the Laboratory, off Route 295) and at the Washington National Airport (across the Potomac River NNW from the Laboratory), and/or abnormal weather conditions, then the pollutant concentration trends will be disrupted. Furthermore, the addition of new emission sources without suitable control devices could establish changing trends and increased pollutant concentrations in the ambient air. Relaxing pollution control strategy would also bias the air quality data.

Some additional features that an analysis of the air quality data have shown are:

15

(a) most of the high O_3 concentrations came from the westerly direction, W for SO_2, easterly for CO, and westerly for THC, CH_4 and RHC;

(b) most of the high concentrations occurred at wind speeds less than 10 mph;

(c) some high THC, CH_4, RHC, and NO_2 concentrations have occurred at high relative humidities or overcast conditions;

(d) high O_3 and SO_2 concentrations occur at low relative humidities;

(e) high O_3 concentrations occur with high air temperatures;

(f) high concentrations do not occur at the same time of day for the pollutants of interest;

(g) most of the high pollutant concentrations come from the Virginia sector;

(h) O_3 and SO_2 concentrations are inversely related to each other;

(i) surface-based temperature inversions peak between 7:30 a.m. - 8:30 a.m. (another example of a systematic variation);

(j) RHC and SO_2 concentrations have the greatest variability among the pollutants measured at the Laboratory; this would appear to indicate that sources of these two pollutants are nearby since insufficient time has elapsed for more thorough mixing;

(k) THC and CH_4 concentrations have the least variability and would appear to indicate a more thorough mixing process for these gases;

(l) O_3, NO_2, and CO concentrations reveal an intermediate variability lying somewhat between a poorly mixed atmosphere and a well mixed atmosphere;

(m) some RHC concentrations might have a non-combustion source, i.e., biological, evaporation;

(n) the highest value that $(C_{mx})_{1-hr}$ can have is $24 \cdot (C_{avg})_{24-hr}$;

16

(o) it is possible that some pollutants are recycled through the atmosphere back to the point of observation;

(p) a pollutant measured at one certain time of day may be from a source different from that measured at other times;

(q) a longer time-averaging period standard will be more frequently violated than a shorter time-averaging period standard;

(r) $(C_{MAX})_{5-min}$ can never be greater than $12 \cdot (C_{AVG})_{1-hr}$ for the hour in which the measurements are made; generally, $(C_{MAX})_{5-min}$ is less than three times the hourly average. The only exception appears to be the RHC data; this indicates that RHC passes the air sampling probe as a series of discrete puffs since a number of hourly averages of this pollutant have zero concentration. This further indicates that there must be a nearby source of RHC since there has not been enough time for mixing;

(s) some pollutants are more well-mixed in the atmosphere than other pollutants;

(t) the order in which pollutant concentrations show decreasing variability are RHC, SO_2, O_3, NO_2, CO, THC, and CH_4 (RHC having the greatest variability and CH_4 the least change in concentration).

SUMMARY

The pollutants and gases measured at the NRL air monitoring station include ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), total hydrocarbons (THC), methane (CH_4), and carbon monoxide (CO). The meteorological conditions are the wind speed and wind direction. The data input from the instruments measuring the variables are presented in the format of a monthly computer printout. The body of information contained in this report is a summary of the monthly computer printout air quality data for the calendar year 1978. The main features of the 1978 annual summary includes for each variable: the monthly averages, representative yearly average, maximum concentrations at various time-averages, prevailing wind directions, number of times the federal and local air quality standards were exceeded, and trends and characteristics of pollutant behavior in the atmosphere. One of the main points in the report is that some pollutant concentrations follow a daily

17

cycle in their behavior due to the systematic variations caused by factors such as daily emission schedules and/or meteorological conditions.

18

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